

PROCEDURE TO INHIBIT OR ELIMINATE ACID GAS GENERATED IN PROCESS OF ELECTROWINNING OF COPPER

The present application relates to a method for inhibiting or suppressing the formation of acid mist above the electrolyte free surface area in electrowinning (EW) methods, during the recovery of copper from acid aqueous solutions generated by leaching (LIX) and Solvent Extraction (SX) methods, in copper hydrometallurgy. Specifically, it relates to a method for inhibiting or suppressing the formation of acid mist above the electrolytic cells for metal electrowinning, through the use of a surfactant agent. This agent is constituted by macromolecules of triterpenic saponins, contained in the Quillaja Extract (obtained from the Quillaja saponaria Molina tree), based on carbon, hydrogen and oxygen atoms, and soluble in acid electrolytes, such as sulfuric acid containing copper in solution.

BACKGROUND

The recovery of copper from ores by the leaching (LIX), Solvent Extraction (SX) and Electrowinning (EW) methods is widely known. See U.S. Patent No. 4,484,990 (Bultman et al.).

Generally, the oxidized copper ores are dissolved or leached with acid aqueous solutions, thus generating a liquor having copper dissolved therein. The aqueous solution (PLS) is contacted with a water-immiscible organic solvent containing a copper-selective ion exchange agent. In this same step, the organic phase (loaded with copper) and the aqueous (copper-depleted) phase are separated in settler tanks.

Subsequently, the copper contained in the loaded organic phase is stripped by contacting it with an aqueous solution containing low copper content and a high acidity, known as Spent Electrolyte, which is the aqueous output of the EW method. The aqueous solution loaded with copper (coming from the contact with the organic phase) is usually referred to as Rich Electrolyte. The copper solubilized in this electrolyte is electrochemically recovered as

cathode copper by the EW method. The remaining solution having a low copper content and referred to as Spent Electrolyte, is recirculated to the SX method, such that, in a continuous and closed circuit operation its main function is to receive copper from the loaded organic by a mass transfer mechanism.

The EW method, through the application of an electric current, permits the electrodeposition of elemental copper at the cathodes. As a result of the electrochemical reactions at the anode, huge amounts of oxygen gas and, in a much lesser proportion, chlorine gas are generated at the surface area of the insoluble anodes. The evolution of these gases forms bubbles at the anode/electrolyte interface, that rise to the surface of the electrolyte in contact with atmospheric air, where they burst and entrain strongly acid electrolyte, which is expelled into the air in the form of a fine mist of spray-type droplets that spread above the electrolytic cells throughout the EW tankhouse. This acid mist causes, among others:

a) a health hazard for tankhouse workers since it affects the respiratory system, eyes and skin, b) corrosion in the metallic structures of the EW tankhouse, c) damage to the instrument systems, and d) environmental contamination in the surroundings of the SX/EW plant. In order to decrease the deleterious effects of the acid mist generated in EW plants, various physical and chemical agents are applied.

Among the most common physical agents, mention should be made to the use of floating balls, either hollow or dense, made of polypropylene and of a standard size, that act as a barrier when the bubbles that generate the acid mist burst. Up to three layers of floating balls are placed on the free surface of the electrolyte.

In relation to other physical agents employed to decrease the impact and damage caused by the acid mist, regarding the above mentioned features, there can be recited the disclosures of Chilean Invention Patents Nos. 35,991 and 36,367. These documents describe a coalescer equipment for the gas bubbles generated in one of the electrodes immersed in a determined electrolyte. To this effect, a baffle is affixed such that it projects from the electrolyte

through the upper zone of the electrode. This baffle is provided with openings to expel the gas bubbles toward a zone from where they are conveyed by appropriate means. On the other hand, Chilean Invention Patent No. 39,673 discloses a device which permits to cover the electrolyte surface hermetically, and has an opening for the joint evacuation of electrolyte and acid mist.

The physical agents disclosed for decreasing the acid mist in electrolytic methods for the recovery of copper have the disadvantage of acting on the already formed gas bubbles, introducing significant disadvantages to the EW tankhouse, which may affect operating parameters, such as, localized corrosion of permanent cathodes, mechanical stability of the electrodes, detachment problems in cathode copper sheets, etc. Additionally, the costs associated with these disadvantages and the operational maintenance thereof, could involve high capital investment and an important increase in operating costs.

Among the chemical agents employed to decrease the impact and damage caused by the acid mist, regarding the above mentioned features, there can be mentioned the disclosure of Chilean Invention Patent Application No. 580-95 and US Patent 5,468,353 which describes a fluoroaliphatic surfactant supplied to an acid aqueous electrolyte, which decreases the electrolyte surface tension and thereof the size of the gas bubbles generated at the anodic electrode. In an EW method, this decrease in surface tension stabilizes the bubbles and minimizes the generation of acid mist.

However, the chemical surfactant agents of the fluorochemical type have a high unit cost and, in some cases, may affect the phase separation times in the SX method, thus generating serious operating problems. In that respect, US Patent 5,468,353 suggests operating at high temperatures.

Therefore, there arises the need for alternative surfactants to overcome the disadvantages presented in the previous art.

SUMMARY OF THE INVENTION

The method proposed through the use of chemical surfactant agents, such as the extract from quillaja (Quillaja saponaria Molina), permits to decrease the acid mist in EW methods for the recovery of copper acting on the electrolyte surface tension and indirectly on the formation of gas bubbles, in contrast to the physical agents which act on the bursting of the bubbles onto the free surface of the electrolyte.

Additionally, the alternative surfactant described here has the advantage over the physical agents that the triterpenic saponin type of surfactant used in this invention is soluble in the electrolyte and does not interfere with the SX operations. For example it has no impact on the phase separation steps that follow the extraction, washing and stripping steps.

With adequate dosages of quillaja extract for decreasing the acid mist to the levels established by the environmental regulations, a "foam blanket" is not necessarily formed on the free surface of the electrolyte during the EW method. Also, the alternative surfactant described in the present invention reduces acid mist formation with insignificant foam generation upon the polyethylene spheres arranged on the electrolyte surface in the electrolytic cells.

The quillaja extract used in the present invention is derived from the aqueous extraction of Quillaja saponaria Molina, an indigenous tree from Chile. The non-refined aqueous extracts from quillaja contain, among others, triterpenic saponins, sugars, proteins, mucilages, polyphenols and salts. Typical saponin values based on total quillaja solids are 20-45% w/w, typically 20-25 % w/w, although the product can be concentrated to 40-45% solids. Refined aqueous quillaja extract contain approximately 75-80% w/w saponins, based on total solids. Remaining solids are being minor concentrations of sugars, proteins, mucilages, polyphenols and salts. An analysis of the saponins in Quillaja can be found in Nord et al., *Anal. Chim. Acta* 446 (2001) 199-209.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 represents a graph of case 3, an industrial scale application example of the invention, wherein (1) represents the aerosols in bank 1, (2) represents the aerosols in bank 2, and (3) the dosage of the additive supplied to EW consisting of Refined Quillaja Extract diluted in Rich Electrolyte.

Figure 2 represents a graph of case 3, an industrial scale application example of the invention, wherein (4) represents the dosage of the additive supplied to EW consisting of Refined Quillaja Extract diluted in Rich Electrolyte, (5) represents the aerosols in bank 4, and (6) represents the aerosols in bank 3.

Figure 3 represents a graph of case 3, an industrial scale application example of the invention, wherein (7) represents the dosage of the additive supplied to EW consisting of Refined Quillaja Extract diluted in Rich Electrolyte, (8) represents the aerosols in bank 6, and (9) represents the aerosols in bank 5.

Figure 4 represents a graph of case 2, a semi- industrial scale application example of the invention, wherein (10) represents the dosage of the additive supplied to EW consisting of Refined Quillaja Extract diluted in Rich Electrolyte, and (11) represents the decrease in aerosols in the EW cell with the use of an additive containing Refined Quillaja Extract.

Figure 5 represents a graph of case 2, a semi- industrial scale application example of the invention, wherein (12) represents the temperature of the electrolyte in the EW cell, and (13) represents the decrease in aerosols in the EW cell with the use of an additive containing Refined Quillaja Extract.

Figure 6 represents a graph of case 2, a semi- industrial scale application example of the invention, wherein (14) represents the copper concentration, and (15) represents the decrease in aerosols in the EW cell with the use of an additive containing Refined Quillaja Extract.

Figure 7 represents a graph of case 1, a pilot scale application test of the invention, wherein (16) represents the dosage of the additive supplied to EW consisting of Refined Quillaja Extract diluted in Rich Electrolyte, and (17) represents the aerosols present.

Figure 8 represents a graph of case 1, a pilot scale application test of the invention, wherein (18) represents the temperature of the electrolyte in the cell, and (19) represents the aerosols present, for the dosage of the additive supplied to EW consisting of Refined Quillaja Extract diluted in Rich Electrolyte.

Figure 9 represents a graph of case 1, a pilot scale application test of the invention, wherein (20) represents the copper grade, and (21) represents the aerosols present, for the dosage of the additive supplied to EW consisting of Refined Quillaja Extract diluted in Rich Electrolyte.

Figure 10 represents the molecular structure of certain triterpenic saponins contained in the Refined Quillaja Extracts. In the structure, R^1 represents a saccharide, R^2 hydrogen or a saccharide, R^3 hydrogen, R^4 acyl or a saccharide and $R^{4'}$ represents a saccharide. R^4 is typically a monosaccharide, $R^{4'}$ is typically an oligosaccharide. Acyl is typically fatty acyl.

DETAILED DESCRIPTION OF THE INVENTION

The method of the present invention for decreasing, inhibiting or suppressing the formation of acid mist in electrowinning (EW) methods, preferably copper electrowinning, mainly comprises adding refined quillaja extract (commercial name Mistop[®]), obtained from the tree Quillaja saponaria Molina and produced by the company Natural Response, Quilpué, Chile, NR. The addition is made to the EW electrolytic solution so as to preferably achieve a saponin concentration between 0.3 and 10.0 ppm, in the EW electrolyte. This concentration range being sufficient to stabilize the gas bubbles generated at the anode, decreasing, inhibiting or suppressing the acid mist in the copper EW method. The extract may be added directly to the

electrolyte or previously diluted in electrolyte before addition, e.g., pumped to the electrolyte, e.g., added to EW in a diluted form as an additive to the electrolyte, or else in a concentrated form directly to the aqueous stream which is continuously entering the EW cell.

During copper SX-EW methods, it is necessary to maintain the desired surfactant dose in the electrolyte, by supplying the additive, which contains quillaja extract, in a continuous or intermittent form.

Triterpenic saponins have, as a basic structure, the quillaic acid triterpene, substituted at the 3-C position with a di- or tri-saccharide and at the 28-C position, with an oligosaccharide through a fucose residue, to which are bonded one or two acyl-groups, see Figure 10.

It is important to mention that the triterpenic saponin type of surfactant, e.g., contained in the conveniently highly refined quillaja extract (commercial name Mistop[®]) which is added to the electrolyte of the EW method, according to the method of the present invention, does not interfere on the: a) SX method in relation to extraction/re-extraction kinetics, phase separation time and characteristics of the organic phase and washing and stripping steps, b) EW method in relation to the electrolyte in which it is totally soluble and stable, and c) physical and chemical quality of the cathodes produced.

Likewise, the surfactant, e.g., contained in the quillaja extract used in the method described in the present invention, decreases the surface tension of the electrolyte in the EW method, to values below 65 Dynes/cm, in the range of 50 to 60 Dynes/cm, at electrolyte temperatures of @ 30°C to 50°C, depending on the dosage of the additive supplied to EW. This is because the surfactant contained in the quillaja extract stabilizes the gas bubbles generated at the anodic electrode during the EW method, to such an extent that the electrolyte trapped on the bubble surface drains from the bubble, while it bursts slowly when it reaches the surface of the electrolyte, and does not burst violently as in electrolytes without a surfactant, thus decreasing the formation of acid mist.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

In the foregoing and in the following examples, all temperatures are set forth uncorrected in degrees Celsius and, all parts and percentages are by weight, unless otherwise indicated.

EXAMPLES

The following examples are given for a better understanding of the present invention and should not be construed as limiting to the scope and objects of same.

Example 1. Effect of refined quillaja extract on current efficiency and cathode quality. Laboratory scale tests.

Laboratory scale copper electrodeposition experiments were conducted employing industrial electrolyte and small size 750-ml EW electrolytic cells, and using a determined experimental configuration. A stainless steel cathode (64 x 120 mm) and two lead anodes (64 x 20 mm) were used. The copper was electrowon on both faces of the cathode, which had a total available area of 125.9 cm². The chemical composition of the input and output electrolyte at the electrolytic cell is shown in Table 1. This chemical composition represents typical electrolytes used in operations of EW methods.

Table 1. Average chemical composition of the industrial copper electrowinning electrolyte used in laboratory tests.

Copper electrolyte Chemical species	EW Input	EW Output
Cu ²⁺ (g/l)	45	35
H ₂ SO ₄ (g/l)	165	175
Fe ³⁺ (g/l)	1.7	1.7
Co ²⁺ (ppm)	140	140
Cl ⁻ (ppm)	27	27

In all the experiments, the copper was electrowon during 6 hours with a constant current density of 300 A/m². The temperature of the electrolyte in the cell was kept constant at 44°C by recirculating the solution through a heat exchanger. The electrolyte was continuously pumped from the feeding tank to the electrolytic cell in order to maintain approximately constant its chemical composition, as shown in Table 1. The refined quillaja extract (commercial name Mistop[®]) was added at the desired concentration for the aqueous solution in the electrolytic cell and in the feeding tank. The current efficiency was calculated as the increase in the cathode mass and was reproducible in different replicated experiments with an experimental error of @ ± 0.5%.

Table 2 shows the effect of the refined quillaja extract dosage (Mistop[®], Natural Response Quilpué, Chile) supplied and the triterpenic saponin concentration in the electrolyte on the current efficiency and the morphological characteristics of the copper deposition at the electrowon cathodes. The morphological characteristics of the copper deposition were analysed by electron microscopy. The results indicated that the addition of refined quillaja extract does not affect the current efficiency or the morphological characteristics of the copper plated out at the cathodes.

Table 2. Effects of the refined quillaja extract dosage and the triterpenic saponin concentration on current efficiency and morphological characteristics of the copper cathodes.

Refined quillaja extract dosage supplied (ppm)	Triterpenic saponin concentration (ppm)	Current Efficiency %	Morphological characteristics of copper cathodes
1	0.18	94.3	Smooth, no nodules
3	0.54	94.7	Smooth, no nodules
5	0.90	94.5	Smooth, no nodules
10	1.80	94.3	Smooth, no nodules
20	3.60	94.3	Smooth, no nodules

Example 2. Effect of refined quillaja extract on acid mist suppression. Pilot plant scale tests.

The pilot plant physically simulates the SX and EW industrial methods. The SX method comprises two extraction steps: E-1 and E-2, one washing step: W-1, and one stripping step: S-1. The organic is the same used in the industrial plant and is continuously recirculated. The total inventory of organic is @ 650 litres. The total inventory of electrolyte is @ 3,500 litres. The PLS has the same chemical composition as the PLS used at industrial scale. The refined aqueous solution is discarded and returned to the leaching heaps. The advance aqueous solution obtained from the stripping step, S-1, is filtered in order to recover the entrained organic and then fed into the EW method. The loaded organic obtained in E-1 is conveyed to a coalescer and subsequently to a settler, in order to recover the entrained aqueous before entering the washing

step. The organic is washed in order to remove any undesirable impurities from same which might impact the EW method.

The EW method includes two cells, each one having a width of 0.70 m, a length of 1.24 m, and a depth of 1.50 m. Each cell comprises two cathodes and three anodes, similar to those used at the industrial plant, and the electrolyte reaches a level of 1.40 m. The cathodes used are made of stainless steel having an effective area of 1 m² with lateral PVC insulators, and the anodes are made of Pb-Ca-Sn. The flowrate of electrolyte to each cell is 14 l/min with an approximate residence time of 2.26 hours. The harvest cycles vary from 5 to 7 days and the current density for operation is variable between 250 and 275 A/m². The mean temperature of the electrolyte is 45°C.

Table 3. Average chemical composition of the EW input copper electrolyte used in pilot plant tests

Copper electrolyte Chemical species	
Copper, Cu ²⁺ , g/l	40
Sulfuric acid, g/l	180
Cobalt, ppm	200
Total iron, FeT, ppm	800
Fe ²⁺ , ppm	40
Manganese, ppm	10
Chlorine, ppm	20
Silica, ppm	50
Aluminum, ppm	120

The additive dosage is supplied to the EW method by using 14 liters of rich electrolyte, to which is added the product Mistop[®] consisting of refined quillaja extract, thus permitting a continuous supply of additive during 24 hours at a rate of 10 cm³/min via a peristaltic pump, the additive flow being controlled periodically. Surface tensions were measured on the EW electrolyte with a Kruess tensiometer, Model No. 02221. The platinum ring is immersed in an adequate volume of the electrolyte to be measured, @ 30 ml. The ring is slowly raised from the electrolyte by applying an external force. The force necessary to completely separate the ring from the electrolyte determines its surface tension. The highest force reached per unit of length is the surface tension sought.

Acid aerosols were measured in the acid mist located above the EW electrolytic cells, via a MIE Equipment, model pDR-1000, which determines the aerosols values in suspension instantly, as µg or mg aerosols/m³ air. The method comprised measuring during 30 minutes, at an approximate height of 50 cm above the cathodes ears immersed in the electrolyte contained in the copper electrowinning cells.

The main conditions of the EW method which was carried out without (Example 1) and with refined quillaja extract (Examples 2 to 5) are shown in Tables 4 and 5 and in the Graph for Case 1.

Table 4. Main operational input variables of the copper EW cells during pilot plant tests.

Test	Cell electrolyte flowrate l / min	Current Intensity, Amper	Current Density, Amper/m ²	Voltage, Volt	Electrolyte temperature ° C	Copper ions Concentration in Electrolyte, g / l	Electrolyte acidity g / l
E1	15.3	1100	275	3.9	50.0	41.4	183.1
E2	13.4	1000	250	4.1	42.0	39.8	186.8
E3	13.2	854	214	3.9	46.0	36.5	184.2
E4	14.1	1075	269	4.1	45.0	41.8	179.8
E5	14.1	1000	250	4.0	45.0	39.7	198.5

Table 5. Pilot plant tests. Effect of refined quillaja extract dosage on main electrolyte operational variables and aerosols of the copper EW method.

Tests	Electrolyte surface tension Dynes/cm		Ambient temperature ° C	Aerosol emission, mg/ m ³ air	Refined quillaja extract in electrolyte, ppm
	Input	Output			
E1	62	68	20	3.0	0
E2	65	51	20	2.0	5
E3	52	50	21	1.5	8
E4	52	51	20	0.7	18
E5	43	44	17	0.2	32

Example 3. Effect of refined quillaja extract on acid mist suppression. Semi-industrial plant scale tests.

The semi-industrial plant consists of 8 cells, 61 anodes and 60 cathodes, and was operated at the same industrial plant location. Six of the eight cells were arranged in a closed circuit with a stainless steel tank having a capacity of 30 m³ that provides the electrolyte, which may be commercial or scavenger or a mixture of both, while the 2 remaining cells are left in open circuit. The tank had two heaters in order to maintain a constant temperature of the electrolyte in the EW cells. The average flowrate of electrolyte to the cells was 14 m³/h.

Table 6. Average operating conditions during semi-industrial copper EW plant scale tests.

Electrolyte flowrate, m ³ /h	Flowrate of electrolyte recycled to industrial plant, m ³ /h	Electrolyte temperature, °C	Copper concentration in electrolyte, g / l	Current density, A/m ²
72	28	44	42	285

The additive dosage was supplied to the EW from two alternating independent plastic tanks, each one having a capacity of 1 m³. The additive was prepared with refined quillaja extract, Mistop[®], which was diluted in approximately 720 litres of commercial electrolyte, to attain a concentration of 6 ppm of refined quillaja extract in the EW electrolyte. The additive containing refined quillaja extract diluted in rich electrolyte was prepared every 12 hours using a centrifugal pump, with an additive flowrate containing refined quillaja extract/rich electrolyte of 1 l/min, thus maintaining a continuous 24 h operation in the semi-industrial plant.

Surface tension was measured in the EW electrolyte with a Fisher tensiometer, model No. 21, using a platinum ring with a circumference of 6 mm. The methodology of the measurement was similar to that disclosed in Example 2.

Acid aerosols were measured in the acid mist via MIE Monitors, models pDR-1000 and pDR-1200. Both models determine the value for aerosols in suspension instantly, as µg or mg of aerosols/m³ air. The difference between models pDR-1000 and pDR-1200 is that the latter has a pump which guarantees a higher certainty in the measured flow or volume, and permits a bigger air sampling volume for the measurement of acid mist. The technique comprised measuring during 30 minutes at an approximate height of 1.50 m above the electrolyte free surface in the EW cells.

Comparative tests were conducted for the measurement of sulfuric acid contained in the acid aerosol determined by MIE, and using the method of silica-gel tubes and analysis by ion-chromatography. The values obtained by MIE/silica tubes are consistent and corresponding. This means that @ 30 to 40% of the aerosol measured by MIE is acid mist in the form of sulfuric acid.

The main operating conditions of the EW method without (Example 1) and with refined quillaja extract (Examples 2 to 4) are shown in Table 7 and in the Graph for Case 2.

Table 7. Effects of the refined quillaja extract dosage on acid mist suppression and operational parameters during semi-industrial copper EW tests

Tests	Refined quillaja extract dosage, ppm	Electrolyte surface tension Dynes/cm		Temperature, ° C		Aerosols Zone 1, mg/ m ³ air		Aerosols Zone 2, mg/ m ³ air	
		EW Input	EW Output	EW electrolyte	Ambient	Without QE	With QE	Without QE	With QE
E1	0	51	62	43	22	1.1	-	2.9	-
E2	1	50	49	40	10	1.9	1.6	2.7	2.3
E3	4	62	52	41	20	2.3	1.2	3.4	2.5
E4	6	61	63	41	17	0.7	0.4	1.3	0.9

N.B.: Zone 1 and Zones 2 correspond to the lateral hallway and central aisle of the semi-industrial plant, respectively.

Example 4. Effect of refined quillaja extract on the suppression of acid mist. Industrial scale application.

The industrial EW tankhouse has a production capacity of 300,000 metric tons of fine copper per year, and consists of a building having a length of 493 m and a width of 40 m. This tankhouse uses 984 cells made of polymeric concrete in a back-to-back arrangement, divided into six banks, wherein 128 cells correspond to the scavenger circuit and 856 are commercial cells. Each cell comprises 61 anodes and 60 cathodes. The distance between electrodes is 100 mm, the anodes are made of laminated Lead-Calcium-Tin, the area for cathode deposition is 1 m² and the harvest cycle is 6 to 7 days. The plant has six transformers/rectifiers with a maximum current of 35,000 Amperes.

The plant uses Kidd technology for permanent cathodes, having three detaching machines. As a complement, there are used four Femont travelling cranes and a chimney system for removing acid mist through Desom technology design. The automatized travelling cranes are programmed to operate linked to the copper cathode detaching machine. They are equipped with laser telemetry, short circuit detectors with infrared sensors, equipotential bar contact washing, cathode sampling and person's detector.

The reaped cathodes pass through a rejection station for the products that do not meet the required physical quality, while the accepted cathodes continue toward a sampling station and then to a corrugation station in an alternating manner, wherein finally the packages are prepared to be loaded onto trucks and sent to port and from there to their final destination.

The average flowrate of rich electrolyte fed into the EW cells is 15 m³/h. The effective volume of each cell is 10 m³, resulting in a mean residence time of the electrolyte in the EW cell of 40 minutes. The total inventory of electrolyte is about 27,000 m³.

The average operating conditions of the EW method are shown in Table 8.

Tabla 8. Average operating conditions of the EW commercial cells during supply of quillaja extract to whole plant

Electrolyte flowrate m ³ /h		Discarded electrolyte flowrate, m ³ / h	Electrolyte temperature °C		Electrolyte Cu concentration g / l			Current Density, A / m ²		
Scavenger	Commercial		Scav.	Commer.	Scav.	Commer	Spent	Bank 1-2	Bank 3-4	Bank 5-6
2355	12097	26.8	38.9	45.2	53.2	40.8	38.7	268	268	275

In this case, the additive consisting of refined quillaja extract was not dosed into the plant electrolyte to be supplied to EW. Instead, refined quillaja extract was added directly to the electrolyte which feeds the commercial cell circuit via an injection pump to the main electrolyte feed line. Surface tension was measured with a Fisher tensiometer, model No. 21, using a platinum ring with a circumference of 6 cm. The measurement methodology was similar to that disclosed in Example 2.

Acid aerosols were measured in the acid mist via MIE Monitors, models pDR-1000 and pDR-1200. Both models determine the value for aerosols in suspension instantly, as µg or mg aerosols/m³ air.

Two central cells of each bank and the middle points of each cell were selected as measurement points for aerosols. In this way, two values were obtained which were averaged to obtain the final value for the bank.

The main average operating conditions of the EW method with refined quillaja extract during the acid mist measurements are shown in Tables 8A and 8B and in the Graph for Case 3.

Table 8 A. Main operational input variables in the copper commercial EW cells during whole plant tests.

Tests	Electrolyte temperature, °C	Current density, A/m ²		
		Bank 1- 2	Bank 3- 4	Bank 5- 6
E1	45.5	286	285	288
E2	45.4	275	275	285
E3	45.1	288	288	288
E4	44.7	244	244	253

Table 8 B. Effects of the refined quillaja extract dosage on acid mist suppression and operational parameters during whole plant copper EW tests.

Tests	Concentration of refined quillaja extract in electrolyte, ppm	Electrolyte surface tension Dynes/cm		Aerosols of acid mist above EW Cells mg/m ³ air					
		Advance	Spent	Bank 1	Bank 2	Bank 3	Bank 4	Bank 5	Bank 6
E1	2.8	60.8	60.6	0.6	1.4	1.3	1.8	1.4	1.5
E2	6.0	61.2	62.3	0.5	1.0	0.9	1.2	1.3	1.2

E3	8.0	56.8	55.7	0.4	0.8	0.6	1.0	0.6	1.0
E4	8.0	55.7	54.4	0.3	0.6	0.3	0.7	0.4	0.5

The entire disclosure[s] of all applications, patents and publications, cited herein and of corresponding Chile application No. 1869-2002, filed August 19, 2002 is incorporated by reference herein.

The preceding examples can be repeated with similar success by substituting the generically or specifically described reactants and/or operating conditions of this invention for those used in the preceding examples.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.